BASIC SCIENCE SERIES

1 AIR
2 EARTH
3 ELECTRICITY
4 FORCES AND MEASUREMENTS
5 HEAT
6 LIGHT
7 LIVING THINGS — ANIMALS
8 LIVING THINGS — MAN
9 LIVING THINGS — PLANTS
10 MAGNETISM
11 SOUND
12 WATER
13 ANIMALS AND THEIR YOUNG
14 SPACE AND MAN
15 LIFE IN THE SEA
16 ATOMS

BASIC SCIENCE SERIES

FORCES AND MEASUREMENTS

REVISED EDITION

BASIC SCIENCE SERIES — BOOK 4

REVISED EDITION

FORCES AND MEASUREMENTS

FEP INTERNATIONAL PRIVATE LIMITED
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PREFACE

In the present technological era it is important that all children should be given a basic training in scientific knowledge. The Basic Science Series is written with this aim in mind.

The series includes 16 scientific topics each of which is a complete information book. In its entirety the scheme covers the syllabus generally adopted by upper primary classes and lower secondary forms.

The text is supported by attractive illustrations and is written in a style acceptable to a wide range of pupils.

A strong feature of each of the books is the inclusion of many simple experiments under the section "Things to Do". This encourages the pupil to keep his own project book and ultimately assists his understanding of Science.

CONTENTS

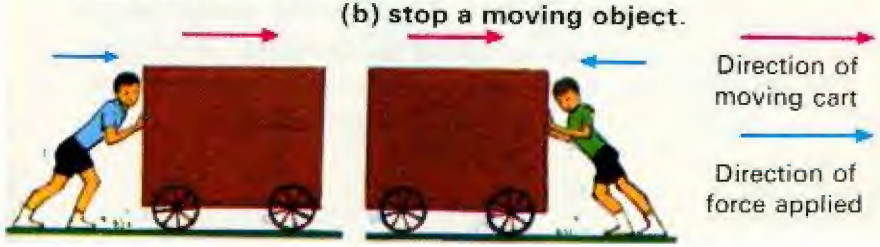
INTRODUCTION

In our everyday life we see many moving things. We see cars, bicycles, buses, lorries and vans moving along the roads. We see aeroplanes flying in the sky and ships sailing in the sea. These are only a few examples of moving things.

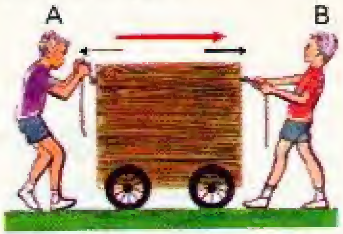
Do you know what causes things to move? The answer is **force**. A force can be a push or a pull. If you exert a force on a cart it will start to move. If you increase the force, the cart will move faster and faster. This is called **acceleration**. If you stop pushing or pulling the cart, it will keep moving for some time before it stops. It is the same when we ride a bicycle. The bicycle will stop moving after some time if we do not keep on pedalling.

If you want to stop a moving cart, you must exert a force on it. In the same way if you want to stop your moving bicycle you apply the brake.

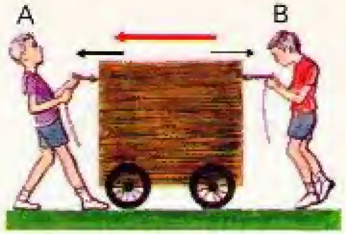
Force is needed to (a) move an object.
(b) stop a moving object.



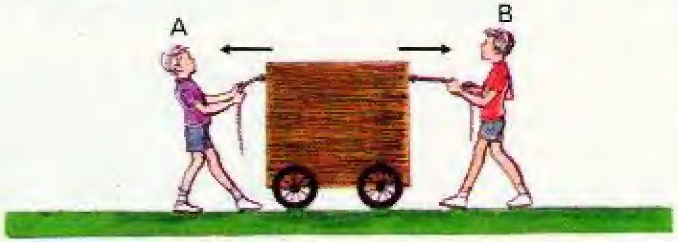
What happens when equal and opposite forces act on an object?



B pulls harder than A



A pulls harder than B



A and B pull with an equal force

If an object is not moving it does not mean that there are no forces acting on it. An object will not move if there are equal and opposite forces acting on it.

WHAT IS WEIGHT?

If you hold a book and then let it go, the book will fall to the ground. The book falls because a force pulls it down. This force is due to the Earth's gravity. The Earth's gravitational pull on an object is called its **weight**. A smaller gravitational force acts on a lighter object and a bigger force acts on a heavier object.

WEIGHING MACHINES

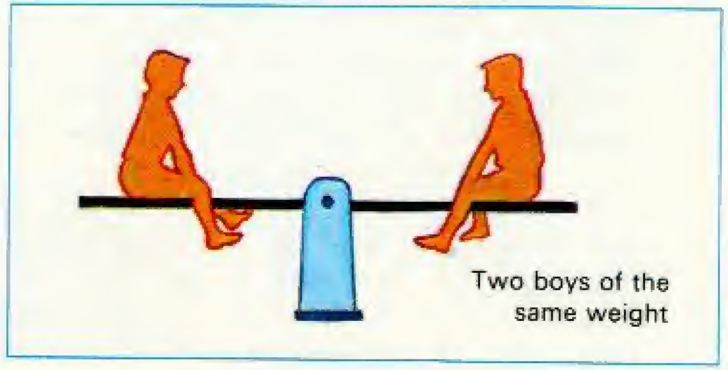
Weighing machines are used to find out the **weights** of objects or to compare the weights of different objects. There are many kinds of weighing machines. Next time you go shopping or marketing, find out the different ways in which shop-keepers weigh things.

Now let's find out more about the weighing of things and weighing machines. First, let us find out about a **see-saw**, which can be used as a simple weighing machine. Then we will find out how to make simple weighing machines and how to use them.

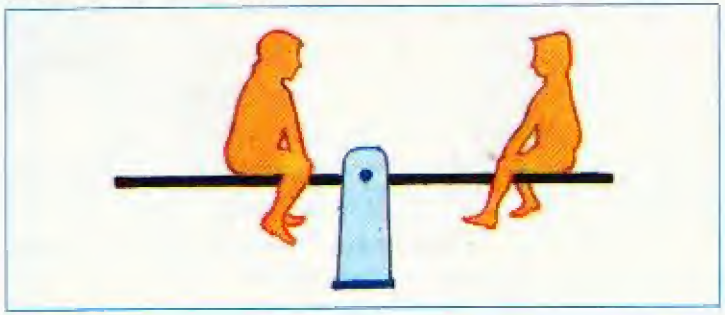
A SEE-SAW

Two boys, both of the same weight, sit on opposite sides of a see-saw. How far must they be from the centre in order to keep the see-saw balanced?

To balance a see-saw



When two boys of different weights sit on a see-saw, which boy must sit further away from the centre of the see-saw in order to balance it?



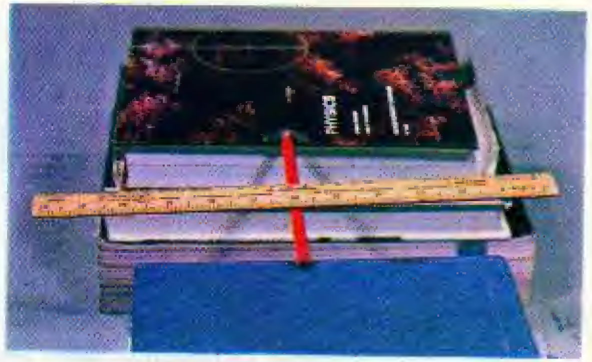
By moving to different positions, they will soon find out that they have to sit at equal distances from the centre. Now, if one of them is heavier, the heavier boy has to be nearer to the centre to make the see-saw balance.

Things to Do

Take a stone in each hand. Can you find out which stone is heavier? If the two stones are about the same size, you may not be able to tell which one is heavier. But you can use a see-saw to find out which one is heavier.

Place a pencil on two piles of books and balance a ruler on it. Now place one stone on each side of the ruler and move them until the ruler is balanced. Find out how far each stone is from the

A balanced ruler



Stones balanced on a ruler

pencil. The stone nearer to the pencil is the heavier one. Now you know how a simple weighing machine works.

SIMPLE WEIGHING MACHINES

There are very simple weighing machines which we can make. One is a **clamp balance** and the other is a **balloon strip balance**. These weighing machines are not very accurate. They do not give us the exact weight of an

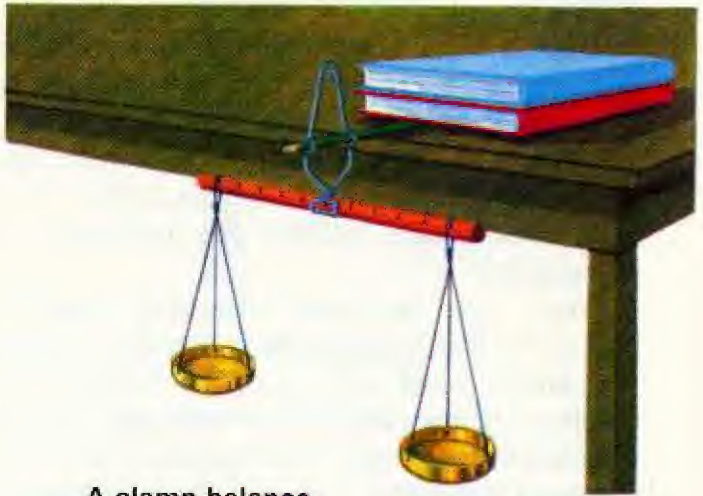
object. Complicated weighing machines are used in shops and factories. Mostly they are very accurate. Some are used for weighing meat, fish, peanuts, vegetables and other things, while some are used for weighing people.

Things to Do

(i) Let's make a simple weighing machine called a clamp balance. For your clamp balance, you will need a clamp, a wooden rod about 1 metre long, a round pencil, two similar tin lids, each with three small holes, and a piece of thin string.

First of all, put one end of the pencil under some heavy books so that the other end juts out over the edge of a desk. Next, put the two wire holes of the clamp on to the pencil so that the clamp swings freely. By opening and shutting the clamp, place the wooden rod in a position where it balances. Make pencil marks at each end of the rod at equal distances from the clamp. Using a razor blade, make a little groove at each pencil mark. The grooves are for keeping the strings in place.

Now, to make the scale pans, tie the thin string to the three holes in the tin lids. Next, hang the scale pans from the grooves, first making sure that the rod is level. The pans must be placed



A clamp balance

at equal distances from the clamp. Do the pans balance? If they do not, stick some plasticine on the lighter pan. Now your clamp balance is ready for use.

Use your weighing machine to compare the weights of some objects such as peanuts, rubber, chalk and small stones. Place these objects on the scale pans and balance them with other objects. Find out which objects are heavier and which are lighter.

(ii) To compare the weights of different objects properly, we must have standard weights. We can make our own standard weights by filling bottle-tops with plasticine. Now balance these bottle-tops

against one another. Make sure they all weigh the same by taking away or adding plasticine to them. We will call these standard weights 'sprogs'.

Place a sprog on one scale pan and some identical buttons on the other. Find out how many buttons are balanced by one sprog.

You can use your weighing machine to find the weight of a stone, a pen, a small ruler and so on. Place the object in one scale pan and put sprogs in the other until the balance is level. Record the weight of the object in sprogs. Now replace the sprogs with blocks. Record the weight of the object in blocks also.

(iii) We can make another simple weighing machine called a rubber strip balance. Cut a rubber strip 1 cm wide and 10 cm long. Tie one end of the rubber strip to a stick and the other end to a scale pan as shown in the picture. Attach a paper clip pointer at the place where the scale pan is tied to the rubber strip.

Hang your rubber strip balance over the side of a desk and put a heavy weight on the stick to hold it firmly. Now pin a piece of cardboard on the side of the desk so that a scale can be marked on it.

A rubber strip balance

You can mark the scale in this way. Mark the position on the cardboard where the pointer lies when there is no sprog on the scale pan. Write 0 (zero) against this mark. Now place one sprog on the pan. You will find that the pan moves down a little. Mark the new position of the pointer on the cardboard. Write 1 for '1 sprog' against the new mark. Add more sprogs one by one and mark the position of the pointer each time. Write 2, 3, and so on against the marks. Now remove the sprogs one by one and check that the marks are still correct. Now you have made a rubber strip balance.

(iv) We can use this machine for weighing things like stones, books, dusters and so on. We put the stone on the scale pan and read off the position of the pointer

on the scale. If the pointer lies between the '3 sprogs' and '4 sprogs' mark, we say that the stone weighs more than 3 sprogs but less than 4 sprogs. Record the weights of all the other objects in this way.

WHAT IS WORK?

When you push against a big rock and if it does not move, then in the language of Science, you are not doing any work. Can you consider yourself working when you are studying or talking?

In Science, work is only done when a force moves something that has weight through a distance.

Work = force × distance moved

The unit of work is in **joules**, if the force is measured in **newtons** and distance in **metres**.

THE PULLEY

Sometimes we find that a piece of work cannot be done by us because the load is too heavy. We have to use something to make the work easier for us. Pulleys help to make work easier for us.

The pulley is a grooved wheel. The pulley, used together with a rope or chain, is used to lift heavy weights or to change the direction of a force.

A pulley can be used in two ways:

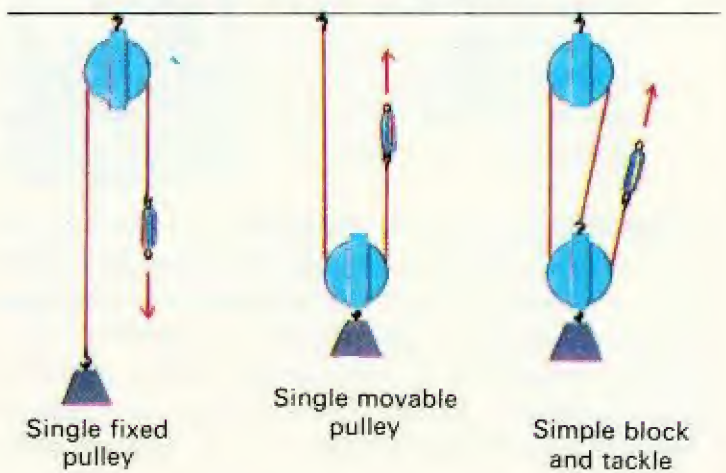
(*a*) it can be fastened by means of a hook to some support — a **fixed pulley**.

(*b*) it can be fastened to the load — a **movable pulley**.

A SINGLE FIXED PULLEY

The simplest type of pulley is the single fixed pulley. It is most commonly used on flag-poles. You must have noticed that when a person raises a flag up a flag-pole he pulls the rope downwards so that the flag goes up. A string, tied to the flag, is passed over a pulley which is fixed to the top of the flag-pole. By pulling at the free end of the string coming down from the pulley the flag will be raised.

Some common pulley systems



Things to Do

(i) You can lift up a large pail of water by using a pulley. Fix a pulley to a beam in your classroom. Pass a string over the pulley and tie one end of the string to the handle of the pail. Pull at the other end of the string. Is it easier to lift up the pail of water by using a pulley or to do so with your bare hands?

(ii) You can use a pulley to pull a heavy carton of sand across a table. Tie a string around the carton and move it by pulling on the string. Is it difficult to move it? Now ask someone to hold a pencil at one end of the table. Loop the free end of the string round the pencil. Move the carton away from you by pulling the string towards you. Now replace the pencil with a pulley. Thread the string around the pulley. Try to move the carton again by pulling the free end of the string towards you. Is it easier to move the carton by using the pulley or the pencil?

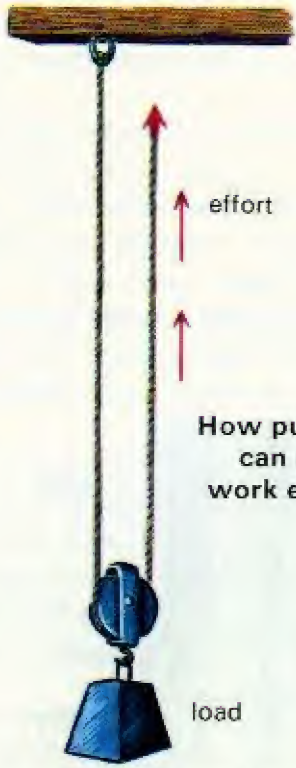
A SINGLE MOVABLE PULLEY

A single movable pulley is used in this way: a string is fixed to a support. The free end of the string goes round the pulley. The weight to be lifted is hung on the pulley and the effort is applied at the free end of the string. By pulling the free end of the string upwards, the

Without a pulley

Using a single fixed pulley

How pulleys can make work easier



a single movable pulley

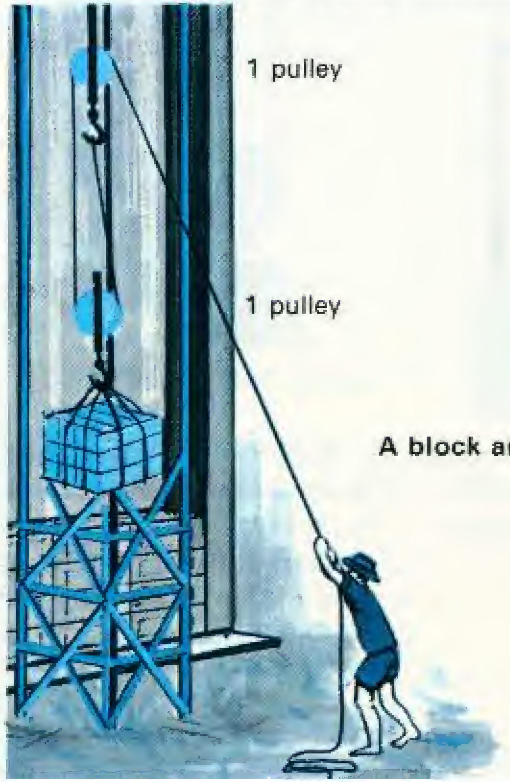
weight is lifted upwards. Also, you will find that lifting the weight is much easier using the pulley than without it.

In the single fixed pulley system, the load is supported by one section of the string. In the single movable pulley system, the load is supported by two sections of the string. You will

find that the effort needed to raise the same load is much less in the single movable pulley system than in the single fixed pulley system.

THE BLOCK AND TACKLE

For some work, like the raising of a very heavy load, even the use of a single pulley, whether fixed or movable, does not make the work very much easier. In such cases, a **block and tackle** system is used. This system is made up of two pulleys, one fixed and one movable with a single rope going round them.



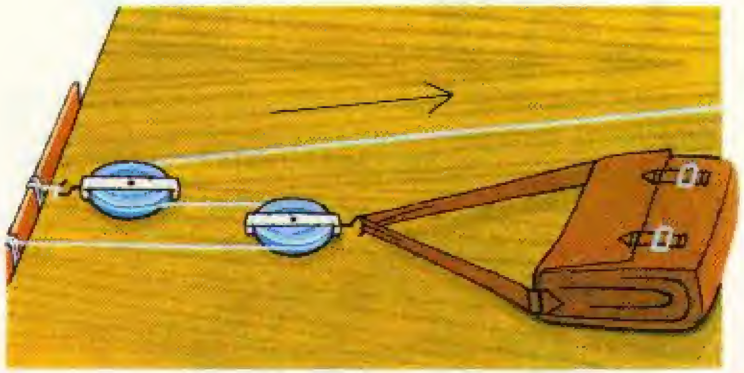
A block and tackle in use

Things to Do

You can use two pulleys to make work easier. You will need a bag full of sand, a ruler, two pulleys and a piece of string about 3 metres long. Put the bag at one end of the table and the ruler at the other. Hook the bag to Pulley No. 1 and tie the hook of Pulley No. 2 to the ruler. Tie one end of the string to the ruler, and thread the other end of the string around Pulley No. 1 and then around Pulley No. 2. You have just set up a block and tackle system.

Ask someone to hold the ruler firmly in place against the end of the table. Hold the bag and pull it along the table. Now, put the bag back where it was. Hold the free end of the string and pull so that the bag moves. Do you notice the difference?

A simple two-pulley system

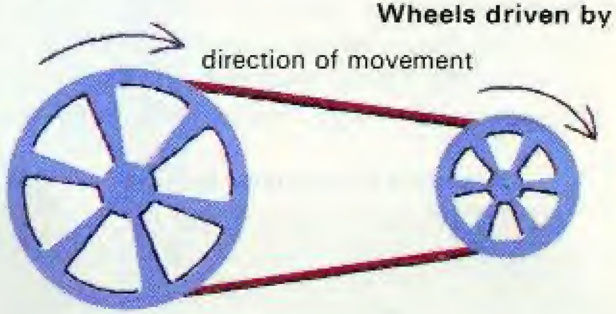


You will find that you require very little effort to move the bag when you use the block and tackle system.

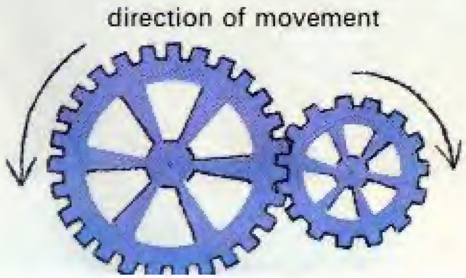
GEARS

Gears are wheels that are used in many machines to transfer circular movement or **rotation** from one part to another. Most wheels are used in pairs. Some wheels have toothed edges while others do not. There are two ways of making both wheels turn. One way is by the use of a belt around the wheels which have smooth edges. The other way is by fitting the teeth of the two wheels together, as shown in the picture below.

Wheels driven by belt



Toothed wheels fitted together



Things to Do

(i) Let's find out how we can make one wheel turn another. You will need one stick, two jar lids of different sizes, one rubber band and two drawing pins. Make a hole in the centre of each lid. Use the drawing pins to attach the lids to the stick and stretch a rubber band around the lids. The lids should be about 2 cm apart. The rubber band should not be too tight. Now turn one of the lids and watch what happens to the other one. Turn the larger lid about five times and count how many times the small lid turns.

Number of turns of large lid	Number of turns of small lid
5	
10	
	20

(ii) Next, remove the rubber band and twist it into a figure-of-eight. Stretch it around the two lids and repeat what you did earlier. What do you notice?

(iii) Take a bicycle and turn it upside-down. Slowly turn its pedals. How do the wheels and pedals turn? How many times does the back wheel turn for one turn of the pedals?

MEASUREMENT

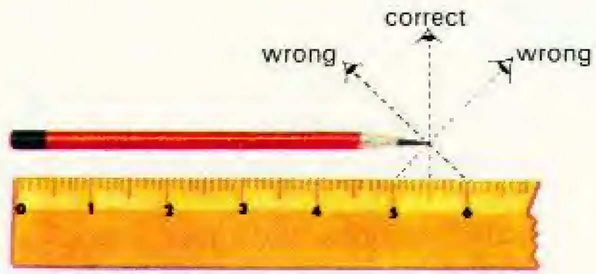
When you ask a boy to find the length of a string, he will reach for a ruler or scale. If there is no ruler around, he can give a rough answer by comparing the string with a familiar object. This was actually the method used by people in the early days. They compared the unknown length with lengths of familiar objects.

As years went by, more and more accurate methods of measurements of length were invented. Today, we have basic units such as the **metre** and the **yard** which we use when measuring lengths. We shall use **centimetre** as the basic unit of measurement.

When you examine an object you will want to know the size of the object. You may want to compare its size with nearby objects whose sizes are known. We use measurements like **length, area** or **volume** when we want to compare the sizes of different objects.

LENGTH

Linear measurements are measurements of length. The length of a straight line can be measured with a ruler. A ruler is a straight piece of material which has a scale of units marked on it. Place a short stick or a pencil by the scale of your ruler and read off the length from different angles. You will notice that all the readings do not agree. The reason is shown clearly in the picture. It is necessary



How to measure a length correctly

for you to position your eyes correctly when reading a scale. The correct position for your eyes is right above the tip of the length you are measuring. Draw several lines or take a few objects and find their lengths in the correct way.

Sometimes, when you want to have very accurate measurements of lengths, you will need a hand lens. The hand lens will magnify the scale. Even if the scale is small, you will be able to read the length accurately.

Things to Do

(i) Let's make a metric tape measure. You will need 1 metre of white cotton tape and a ruler marked in centimetres. Make a blue mark across the tape about a finger's width from one end and write 0 (zero) on it.

By using the ruler, make marks at every centimetre along the tape and write 1, 2, 3, ..., 100 cm against the marks. Cut off the tape about one finger's width past the

100 cm mark. Fold the ends of the tape under and sew, staple or stick them down so that the ends have the reading 0 (zero) and 100 cm exactly.

Now use this tape to measure the length, breadth and height of different objects such as desks, books, and so on.

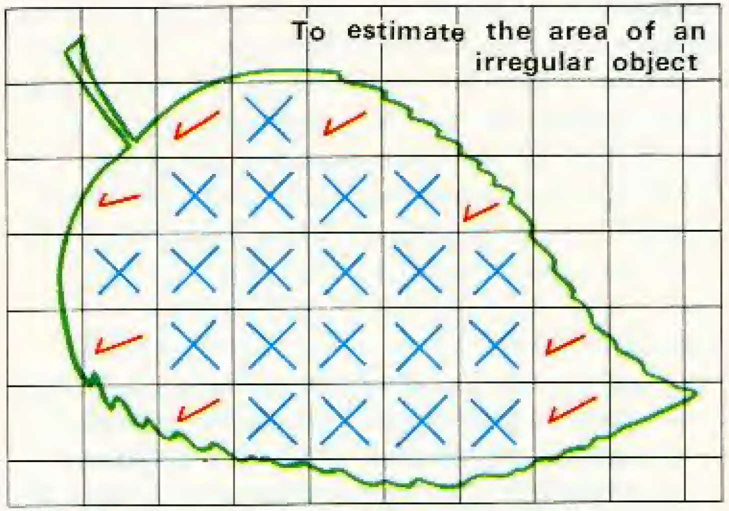
(ii) Use your tape measure to mark a scale in centimetres and metres up the wall. Stand straight up against the scale so that your heels, shoulders and back of your head are touching the wall. Ask a friend to place a ruler or book horizontally on your head and mark your height on the scale.

(iii) Now that you know your own height, can you estimate the height of your chair or desk?

AREA

Areas can be found with the help of units of length. Areas can be **regular** or **irregular**. Examples of regular areas are squares, rectangles and triangles. Leaves, petals and the scales of a fish are objects with irregular areas. Regular areas can be calculated. The area of a rectangle is the product of its length and breadth.

Irregular areas of an object can be determined by tracing its outline on a piece of paper which has squares of sides 1 cm drawn on it. By counting the number of squares inside the outline, the area of an object can be estimated.



Put a × in the complete squares

Put a ✓ in the squares which are more than half covered by a leaf

No. of × = ________

No. of ✓ = ________

Area of leaf = ________ cm²

As each small square is 1 square centimetre, the area of the object will be in square centimetres (cm²).

VOLUME

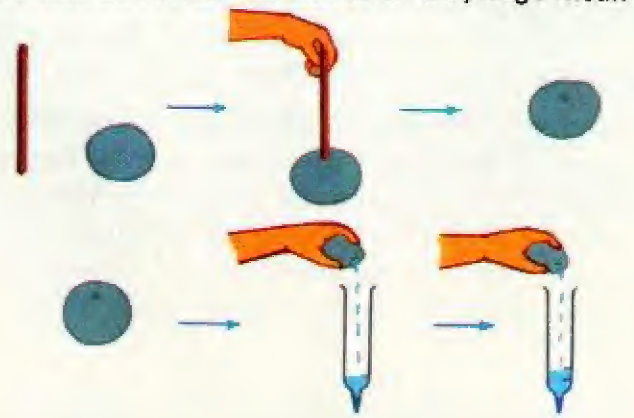
Volume is the size of an object or the amount of space it occupies. An object can be **regular** in shape (i.e. it has a regular volume), or **irregular** in shape (i.e. it has an irregular volume). Cylinders and spheres are examples of objects with regular volumes while stones and fruits are

examples of objects with irregular volumes. Regular volumes can be calculated. The volume of a rectangular box is the product of its length, breadth and height. The volume of a cylinder is the product of the base area and the height. To find irregular volumes, we have to use some other method. Units of volume are cubic centimetres (cm^3) or millilitres (ml).

Things to Do

(i) Let's find out what the marks on a syringe mean. Get a stick of cross-section one square centimetre (i.e. the length and breadth of the cross-section should be 1 cm each). Make marks 1 cm apart from one end of the stick. Take a lump of plasticine and push the stick into the plasticine to a depth of 1 cm. Then take the stick out again. Now you have made a hole in the plasticine and its volume is 1 cubic centimetre (1 cm^3).

To find out what the marks on a syringe mean



Take a syringe and plug its needle hole with plasticine. Fill the hole in the plasticine block with water and pour the water into the syringe. Note the mark to which the water rises in the syringe. This mark is the 1 cm^3 mark. Fill the hole once more and pour the water once again into the syringe. The new mark to which the water rises is the 2 cm^3 mark. By repeating this over and over again, you can find out what all the marks on the syringe mean. The volume of the water at each mark is 1 cm^3, 2 cm^3, 3 cm^3, and so on.

(ii) Fill the syringe up to the 10 cm^3 mark. Drop a small stone into the water. The water level rises. Note the rise in the water level. This rise is equal to the volume of the stone. We use this method to measure the volume of an irregular object which sinks in water.

(iii) Take a plasticine block and make a 1 cm^3 hole in it as you did earlier. Light a candle and let the melted wax drip into the hole until the hole is completely filled with wax. When the wax in the hole has hardened, remove the plasticine carefully. Now you have a wax block with a volume of 1 cm^3. You have made a solid cubic centimetre.

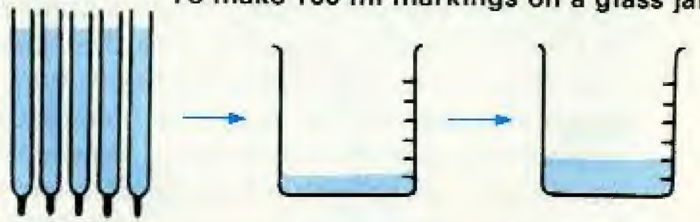
Take the syringe which you used earlier and fill it up to the 10 cm^3 mark. Drop the wax block into the syringe. Does the

wax block sink or float? The water level in the syringe rises but does it rise by one mark (i.e. does it reach the 11 cm³ mark)? Can we say that the volume of the wax block is equal to the volume of water between two marks of the syringe. Why? How can you measure the volume of the wax block?

(iv) Let's mark volumes on a glass jar. First of all, glue a strip of paper on the outside of the jar. Fill a number of syringes up to the 20 cm³ mark. The volume of water in each syringe is 20 cm³ or 20 millilitres (ml). Carefully empty 20 ml of water from five syringes into the jar so that there will be 100 ml of water in the jar altogether. Draw a little line on the paper strip to mark the level of the water and write '100 ml' next to this line.

Repeat the same thing with another

To make 100 ml markings on a glass jar



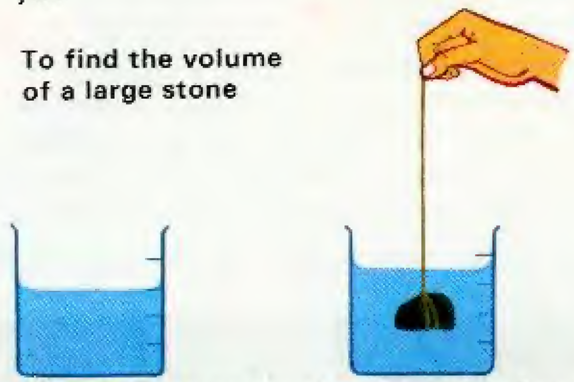
Five syringes, each containing 20 ml of water.

Five lots of 20 ml of water have been poured in.

Another five lots of 20 ml of water have been added.

five lots of 20 ml of water. Draw a line to mark the new water level and write 200 ml against this line. By repeating the same thing over and over again, mark on the paper strip 300 ml, 400 ml, 500 ml and so on, right up to the top of the jar.

To find the volume of a large stone



(v) You can measure the volume of a large stone in this way. Empty your jar and pour water again up to one of the marks. Lower the stone into the jar by means of a string. The water level rises. By how much has it risen? The amount by which it has risen is the volume of the stone.

ENERGY

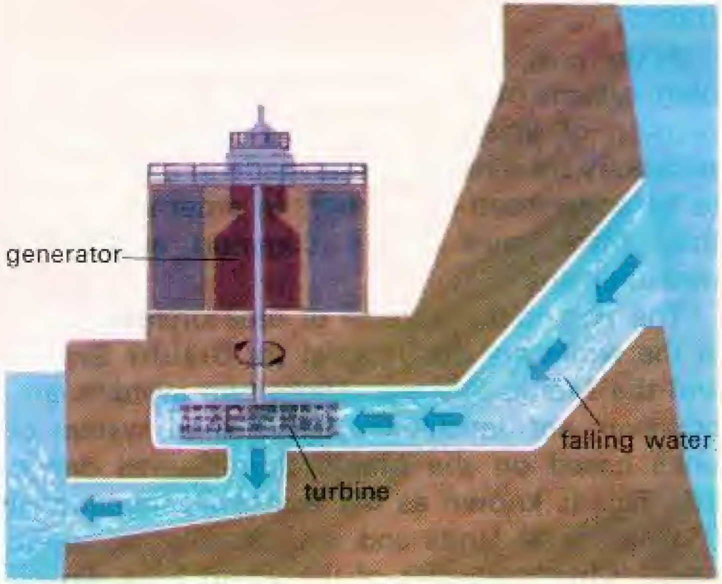
Energy is the ability to do work. Work is done when a force is exerted to move an object over a certain distance. To start a car moving, work must be done on it. To stop the moving car, work must also be done.

The **kinetic energy** of a body is the energy due to movement. A falling pencil has kinetic energy because it is moving. An object is said to possess kinetic energy if it is moving.

The **potential energy** of a body is that due to its height or position. A ball on the slope of a hill possesses potential energy because of its height above the ground. As the ball rolls down the slope the potential energy is converted to kinetic energy.

The water at the top of a waterfall has potential energy. Falling water has kinetic energy due to its motion. This kinetic energy

Water falling from great heights has a lot of kinetic energy.



In a hydro-electric power station, the kinetic energy of water is converted to electrical energy.

can be used to do work. This is the principle of the **hydro-electric generator**. The kinetic energy of the falling water in a dam is used to turn the wheels of a turbine to generate electricity. Here, potential energy is converted first to kinetic energy, then to mechanical energy to turn the turbine. The turbine turns a generator which then produces electricity.

Energy and work are both measured in joules. Power, being the amount of work done per second, is measured in **watts** (joules/sec).

UNITS

In the past, different countries developed their own system of measurement. But with the expansion of Science and world trade it became necessary for measurements made in one country to be understood in another. In order to achieve this, there must be a common system of measurement.

The two main systems of measurement used in the world are the Imperial (or British) System and the Metric System. These two systems are, however, not satisfactory and a third system of units based on the Metric System was drawn up. This is known as the Systéme International d' Units or SI Units and is used in all scientific work. Most countries of the world have agreed to adopt this system.

THE SYSTÉME INTERNATIONAL d' UNITS (SI)

Quantity	Unit	Symbol
mass (weight)	kilogram	kg
time	second	s
length	metre	m
area	square metre	m^2
volume	cubic metre	m^3
speed	metre per second	m/s
force	newton	N
work, energy	joule	J
power	watt	W